

# MATHEMATICS SKILLS IN BASIC SCIENCE AND TECHNOLOGY AS PREDICTORS OF STUDENTS' ACHIEVEMENT IN GENETICS IN NSUKKA EDUCATION ZONE, ENUGU STATE NIGERIA

## COMPETÊNCIAS MATEMÁTICAS EM CIÊNCIAS E TECNOLOGIA BÁSICAS COMO FATORES PREDITIVOS DO DESEMPENHO DOS ALUNOS EM GENÉTICA NA ZONA EDUCACIONAL DE NSUKKA, ESTADO DE ENUGU, NIGÉRIA

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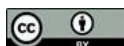
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## **Abstract**

This study investigated mathematics skills in Basic Science and Technology as predictors of students' achievement in genetics. Specifically, the study examined the predictive power of ratio skills, probability skills, and graph interpretation skills on students' achievement in genetics, as well as their joint contribution. A correlational research design was adopted for the study. The population of the study comprised all the Senior Secondary School 3 Biology students in Nsukka education zone, from which a representative sample size of 276 Biology students was drawn using multistage sampling procedure. Data were collected using researchers' designed instruments titled, "Mathematics Skills Test in Basic Science and Technology (MSTBST) covering ratio, probability, and graph interpretation skills, and Genetic Achievement Test (GAT)". The designed instruments were validated. The reliability coefficients of the instruments yielded an indices of 0.92 and .89 for MSTBST and GAT respectively using Kuder Richardson 20 (KR-20) formula. Data collected were analyzed using linear and multiple regression analyses. The findings revealed that ratio skills accounted for approximately 20% of the variance in students' achievement in genetics and significantly predicted achievement. Probability skills accounted for about 27% of the variance and also showed a significant predictive influence. Graph interpretation skills accounted for approximately 16% of the variance and significantly predicted students' achievement, although with a relatively lower contribution. Furthermore, the joint contribution of ratio skills, probability skills, and graph interpretation skills accounted for approximately 51% of the variance in students' achievement in genetics, indicating a strong combined predictive effect. Based on the findings, it was concluded that mathematics skills are significant predictors of students' achievement in genetics. It was therefore recommended that teachers integrate ratio, probability, and graph interpretation skills into the teaching of genetics to enhance students' understanding and academic performance.

## **Resumo**

*Este estudo investigou as competências matemáticas em Ciências Básicas e Tecnologia como preditores do desempenho dos alunos em genética. Especificamente, o estudo examinou o poder preditivo das competências em razão, probabilidade e interpretação de gráficos sobre o desempenho dos alunos em genética, bem como sua contribuição conjunta. Foi adotado um desenho de pesquisa correlacional para o estudo. A população do estudo compreendeu todos os alunos do 3º ano do Ensino Médio do curso de Biologia na zona educacional de Nsukka, da qual foi extraída uma amostra representativa de 276 alunos de Biologia utilizando um procedimento de amostragem em múltiplas etapas. Os dados foram coletados utilizando instrumentos elaborados pelos pesquisadores intitulados "Teste de Habilidades Matemáticas em Ciência e Tecnologia Básicas (MSTBST)", abrangendo habilidades em razão, probabilidade e interpretação de gráficos, e "Teste de Desempenho em Genética (GAT)". Os instrumentos elaborados foram validados. Os coeficientes de confiabilidade dos instrumentos resultaram em índices de 0,92 e 0,89 para o MSTBST e o GAT, respectivamente, utilizando a fórmula de Kuder-Richardson 20 (KR-20). Os dados coletados foram analisados por meio de análises de regressão linear e múltipla. Os resultados revelaram que as habilidades em razão representaram aproximadamente 20% da variância no desempenho dos alunos em genética e predisseram significativamente o desempenho. As habilidades em probabilidade representaram cerca de 27% da variância e também demonstraram uma influência preditiva significativa. As habilidades de interpretação de gráficos representaram aproximadamente 16% da variância e predisseram significativamente o desempenho dos alunos, embora com uma contribuição relativamente menor. Além disso, a contribuição conjunta das habilidades em razão, probabilidade e interpretação de gráficos representou aproximadamente 51% da variância no desempenho dos alunos em genética, indicando um forte efeito preditivo combinado. Com base nos resultados, concluiu-*

**Keywords:** Mathematics Skills. Ratio Skills. Probability Skills. Graph Interpretation. Genetics. Academic Achievement.

*se que as habilidades matemáticas são preditores significativos do desempenho dos alunos em genética. Recomendou-se, portanto, que os professores integrem habilidades de razão, probabilidade e interpretação de gráficos no ensino de genética para aprimorar a compreensão e o desempenho acadêmico dos alunos.*

**Palavras-chave:** Habilidades Matemáticas. Habilidades de Razão. Habilidades de Probabilidade. Interpretação de Gráficos. Genética. Desempenho Acadêmico.

## 1 INTRODUCTION

Basic Science and Technology occupies a central position in the Nigerian educational system, particularly at the junior secondary school level, where it serves as a foundation for the study of core science subjects such as Biology, Chemistry, and Physics. The subject is designed to equip learners with scientific literacy, problem-solving abilities, and functional knowledge necessary for technological advancement and national development (Bybee, 2013; National Research Council, 2012). Within Basic Science, genetics is a critical concept that introduces learners to heredity, variation, and the mechanisms through which traits are transmitted across generations. Despite its importance, students' achievement in genetics has remained persistently low, raising concerns among educators, researchers, and policymakers (WAEC Chief Examiners' Report, 2020; Okafor, 2014).

One of the major reasons attributed to students' poor achievement in science subjects is the inadequate mastery of prerequisite skills, particularly mathematical competencies. Mathematics is widely regarded as the language of science because it provides the tools necessary for quantification, logical reasoning, and interpretation of scientific data (Ogunleye, 2011; Matthews et al., 2009). Research has consistently shown that mathematics skills are strong predictors of students' achievement in science-related disciplines (Mosia et al., 2025; Jerrim et al., 2023). For instance, studies have revealed a strong positive relationship between mathematics skills and students' problem-solving achievement in science, suggesting that deficiencies in mathematical understanding may

directly hinder students' ability to grasp scientific concepts, including genetics (Karakolidis et al., 2024).

Genetics, as a branch of biology, inherently requires the application of mathematical reasoning. Concepts such as Mendelian inheritance, Punnett squares, genotype and phenotype ratios, and genetic probabilities are deeply rooted in mathematical principles. Studies have shown that solving genetics problems requires not only biological knowledge but also the ability to apply statistical and probabilistic reasoning effectively (Özdemir & Clark, 2022; Özdemir et al., 2022). Students who lack these competencies often struggle to interpret genetic crosses, calculate inheritance patterns, and make accurate predictions, which ultimately affect their academic achievement.

Among the various mathematical skills required for understanding genetics, ratio skills play a fundamental role. Ratio is essential for expressing relationships between quantities, particularly in genetic crosses where phenotypic and genotypic outcomes are often represented as ratios. For example, the classical Mendelian monohybrid crosses produces a 3:1 phenotypic ratio, while a dihybrid cross yields a 9:3:3:1 ratio. Understanding these ratios requires proportional reasoning and the ability to compare quantities effectively. Without adequate ratio skills, students may misinterpret genetic outcomes or fail to solve related problems correctly. This aligns with broader research indicating that students' mathematical foundations significantly influence their achievement in scientific contexts (Arbabifar, 2021; Dehipawala et al., 2014; Akinsola & Olowojaiye, 2008).

In addition to ratio skills, probability skills are indispensable in genetics. The concept of probability is used to predict the likelihood of inheriting specific traits, making it a core component of genetic analysis. Studies have shown that probability problems in genetics require students to apply calculation skills alongside conceptual understanding of independent events and the product rule (Özdemir & Clark, 2022). However, many students experience difficulty in applying probability principles correctly, often due to misconceptions or inadequate mathematical preparation. Errors such as incorrect assignment of probabilities or misuse of probabilistic rules are common and significantly reduce students' chances of arriving at correct answers. This highlights the importance of

integrating probability instruction into science teaching to enhance students' comprehension of genetics (Kumar et al., 2020).

Graph interpretation is another critical mathematical skill that influences students' achievement in genetics. In modern science education, data are frequently presented in graphical forms such as bar charts, line graphs, histograms, and scatterplots. Students are expected to interpret these graphical representations to identify patterns, trends, and relationships. Research indicates that graph interpretation involves multiple competencies, including analyzing data distributions, estimating probabilities, and making informed decisions based on visual information (Ainsworth et al., 2023). Furthermore, graphing skills have been shown to enhance students' overall understanding of scientific concepts, as they enable learners to visualize abstract relationships and draw meaningful conclusions from data (Sánchez & García, 2024).

The relationship between mathematics skills and academic achievement has been widely documented in educational research. Studies have shown that students with strong mathematical backgrounds tend to perform better not only in mathematics but also in science subjects. For example, research on mathematics achievement has identified several predictors, including prior knowledge, cognitive abilities, and engagement in learning activities (Jerrim et al., 2023). Similarly, mathematical reading and comprehension skills have been found to significantly influence students' ability to solve problems and achieve higher academic outcomes (Zhang et al., 2023). These findings underscore the interconnectedness of mathematics and science and suggest that improving mathematical competencies can lead to better achievement in scientific domains (OECD, 2019).

In the context of Nigeria, the problem of poor academic achievement in science subjects has been linked to several factors, including ineffective teaching methods, inadequate instructional materials, and students' weak background in mathematics. Mathematics is a compulsory subject in Nigerian secondary schools, yet many students demonstrate low proficiency, which affects their ability to cope with science-related tasks (WAEC Chief Examiners' Report, 2020). Studies have emphasized that improving mathematics instruction can significantly enhance students' achievement in both mathematics and science (Kumar et al., 2020; Akinsola & Olowojaiye, 2008). However, traditional teaching approaches often treat mathematics and science as separate

disciplines, failing to emphasize their interdependence. This disconnect prevents students from transferring mathematical knowledge to scientific problem-solving contexts, particularly in genetics.

Furthermore, the increasing emphasis on STEM (Science, Technology, Engineering, and Mathematics) education globally highlights the importance of integrating mathematical skills into science learning. STEM education aims to develop students' critical thinking, analytical reasoning, and problem-solving abilities, all of which rely heavily on mathematical competence (Bybee, 2013; Li et al., 2025). Research has shown that students' success in STEM fields is influenced by their mathematical skills, which serve as a foundation for understanding complex scientific concepts (National Research Council, 2012; OECD, 2019). Therefore, strengthening students' mathematical skills is essential for improving their achievement in genetics and other science-related subjects.

Another important consideration is the cognitive demand of genetics as a subject. Genetics requires students to engage in higher-order thinking skills, including reasoning, analysis, and synthesis. Studies have shown that students who employ reasoning strategies and logical thinking are more likely to achieve correct answers in genetics problems (Özdemir et al., 2022). These reasoning processes are closely linked to mathematical thinking, further reinforcing the role of mathematics skills in enhancing students' understanding of genetics.

Despite the recognized importance of mathematics skills in science education, there is still limited research focusing specifically on how individual mathematical skills, such as; ratio, probability, and graph interpretation predict students' achievement in genetics. Most existing studies have examined mathematics skills in a general sense, without disaggregating them into specific components. However, different mathematical skills may have varying degrees of influence on students' understanding of genetics. For example, ratio skills may be more relevant for interpreting genetic crosses, while probability skills may be more important for predicting inheritance patterns. Similarly, graph interpretation skills may play a crucial role in analyzing genetic data. Therefore, it is necessary to examine these skills individually to determine their specific contributions to students' academic achievement.

In addition, the concept of prediction is important in educational research, as it helps to identify factors that influence learning outcomes and provides a basis for developing effective interventions. Predictive studies enable educators to determine which variables have the greatest impact on students' achievement and to design strategies for improving learning outcomes. In the context of this study, examining mathematics skills as predictors of achievement in genetics will provide valuable insights into the extent to which these skills contribute to students' academic success.

Moreover, the integration of mathematics and science has significant implications for teaching and learning. Interdisciplinary approaches that emphasize the application of mathematical skills in scientific contexts can enhance students' understanding and retention of knowledge. For example, teaching genetics using problem-based learning and data analysis activities can help students develop both mathematical and scientific competencies simultaneously. Such approaches have been shown to improve students' engagement, motivation, and academic achievement (Kumar et al., 2020).

In conclusion, mathematics skills, particularly ratio, probability, and graph interpretation are essential for understanding genetics and achieving success in Basic Science and Technology. The interplay between mathematics and science underscores the need for a holistic approach to teaching and learning, where students are encouraged to apply mathematical concepts in scientific contexts. Given the persistent challenges associated with students' achievement in genetics, it is imperative to investigate the predictive role of mathematics skills in this domain. This study, therefore, seeks to examine how ratio skills, probability skills, and graph interpretation skills serve as predictors of students' academic achievement in genetics, with the ultimate goal of improving teaching practices and learning outcomes.

## **2 PURPOSE OF THE STUDY**

Generally, the study investigated the mathematics skills in Basic Science and Technology as predictors of students' achievement in genetics. Specifically, the study determined the;

1. predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics;

2. predictive power of probability skills in Basic Science and Technology on students' achievement in genetics;
3. predictive power of graph interpretation skills in Basic Science and Technology on students' achievement in genetics;
4. joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics.

### **3 RESEARCH QUESTIONS**

The following research questions guided the study;

1. What is the predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics?
2. What is the predictive power of probability skills in Basic Science and Technology on students' achievement in genetics?
3. What is the predictive power of graph interpretation skills in Basic Science and Technology on students' achievement in genetics?
4. What is the joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics?

### **4 HYPOTHESES**

The following null hypotheses were formulated and tested at .05 level of significance;

1. There is no significant predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics.
2. There is no significant predictive power of probability skills in Basic Science and Technology on students' achievement in genetics.
3. There is no significant predictive power of graph interpretation skills in Basic Science and Technology on students' achievement in genetics.
4. There is no significant joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics.

## 5 METHODS

The study adopted a correlational research design to examine the extent to which mathematics skills in Basic Science and Technology predict students' achievement in genetics. The population of the study comprised all the Senior Secondary School 3 Biology students in Nsukka education zone, from which a representative sample size of 276 Biology students was drawn using multistage sampling procedure. Data were collected using researchers' designed instruments titled, "Mathematics Skills Test in Basic Science and Technology (MSTBST) covering ratio, probability, and graph interpretation skills, and Genetic Achievement Test (GAT)". The instruments were subjected to both face and content validation. The reliability coefficients of the instruments yielded an indices of 0.92 and .89 for MSTBST and GAT respectively using Kuder Richardson 20 (KR-20) formula. For data analysis, linear regression analysis was employed to determine the individual predictive power of ratio skills, probability skills, and graph interpretation skills on students' achievement in genetics, while multiple regression analysis was used to examine their joint predictive effect. Meanwhile, hypotheses 1-3 were tested using regression t-test, while regression ANOVA was used to test hypothesis 4. The level of significance was set at 0.05 for all statistical tests. The results were presented in tables, showing coefficients such as R, R<sup>2</sup>, adjusted R<sup>2</sup>, standard error of estimate, and t-values, which were used to answer the research questions and test the hypotheses.

## 6 RESULTS

### 6.1 Research question one

What is the predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics?

**Table 1**

*Linear regression analysis of the predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.451 <sup>a</sup>	.203	.200	3.24942

(R<sup>2</sup>) = Coefficient of Determination

The regression analysis in Table 1 revealed a moderate positive relationship between ratio skills and students' achievement in genetics ( $R = 0.451$ ,  $R^2 = 0.203$ , Adjusted  $R^2 = 0.200$ ). This indicates that ratio skills account for approximately 20% of the variance in students' achievement, suggesting that students with stronger ratio skills are likely to achieve better results in genetics, although other factors also contribute to academic achievement. The standard error of 3.25 indicates a reasonable level of accuracy in the predictions made by the regression model.

## 6.2 Hypothesis one

There is no significant predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics.

**Table 2**

*Regression t-test analysis of significant predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	29.028	1.284		22.611	.000
	Ratio_Skills	.260	.031	.451	8.357	.000

The result in Table 2 shows that t-value of 8.357 with associated exact probability value of .000 was obtained. This probability value of 0.000 was compared with 0.05 set as level of significance for testing the hypothesis and it was found to be significant since the obtained probability value of 0.000 is less than 0.05. Thus, the null hypothesis of no significant predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics was rejected. The researchers therefore, conclude that there is a

significant predictive power of ratio skills in Basic Science and Technology on students' achievement in genetics.

### 6.3 Research question two

What is the predictive power of probability skills in Basic Science and Technology on students' achievement in genetics?

**Table 3**

*Linear regression analysis of the predictive power of probability skills in Basic Science and Technology on students' achievement in genetics*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.519 <sup>a</sup>	.269	.267	3.11127

(R<sup>2</sup>) = Coefficient of Determination

The regression analysis in Table 3 indicated a moderate positive relationship between probability skills and students' achievement in genetics (R = 0.519, R<sup>2</sup> = 0.269, Adjusted R<sup>2</sup> = 0.267). This suggests that probability skills account for approximately 27% of the variance in students' achievement in genetics. The results show that students with stronger probability skills are likely to achieve higher scores in genetics, although other factors also contribute to academic achievement.

### 6.4 Hypothesis two

There is no significant predictive power of probability skills in Basic Science and Technology on students' achievement in genetics.

**Table 4**

*Regression t-test analysis of significant predictive power of probability skills in Basic Science and Technology on students' achievement in genetics*

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	27.663	1.205		22.951	.000
Probability_Skills	.306	.030	.519	10.053	.000

The result in Table 4 shows that t-value of 10.053 with associated exact probability value of .000 was obtained. This probability value of 0.000 was compared with 0.05 set as level of significance for testing the hypothesis and it was found to be significant since the obtained probability value of 0.000 is less than 0.05. Thus, the null hypothesis of no significant predictive power of probability skills in Basic Science and Technology on students' achievement in genetics was rejected. The researchers therefore, conclude that there is a significant predictive power of probability skills in Basic Science and Technology on students' achievement in genetics.

### 6.5 Research question three

What is the predictive power of graph interpretation skills in Basic Science and Technology on students' achievement in genetics?

**Table 5**

*Linear regression analysis of the predictive power of graph interpretation skills in Basic Science and Technology on students' achievement in genetics*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.399 <sup>a</sup>	.159	.156	3.33757

(R<sup>2</sup>) = Coefficient of Determination

The regression analysis in Table 5 revealed a positive relationship between graph interpretation skills and students' achievement in genetics ( $R = 0.399$ ,  $R^2 = 0.159$ , Adjusted  $R^2 = 0.156$ ). This indicates that graph interpretation skills account for approximately 16% of the variance in students' achievement in genetics. While the result confirms that students with stronger graph interpretation skills tend to achieve better in

genetics, the relatively lower predictive power suggests that other factors also contribute significantly to students’ academic achievement in genetics.

### 6.6 Hypothesis three

There is no significant predictive power of graph interpretation skills in Basic Science and Technology on students’ achievement in genetics.

**Table 6**

*Regression t-test analysis of significant predictive power of graph interpretation skills in Basic Science and Technology on students’ achievement in genetics*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	29.800	1.379		21.608	.000
	Graph_Inter_Skills	.250	.035	.399	7.205	.000

The result in Table 6 shows that t-value of 7.205 with associated exact probability value of .000 was obtained. This probability value of 0.000 was compared with 0.05 set as level of significance for testing the hypothesis and it was found to be significant since the obtained probability value of 0.000 is less than 0.05. Thus, the null hypothesis of no significant predictive power of graph interpretation skills in Basic Science and Technology on students’ achievement in genetics was rejected. The researchers therefore, conclude that there is a significant predictive power of graph interpretation skills in Basic Science and Technology on students’ achievement in genetics.

### 6.7 Research question four

What is the joint predictive power of mathematics skills in Basic Science and Technology on students’ achievement in genetics?

**Table 7**

*Multiple regression analysis of the joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics*

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.712 <sup>a</sup>	.507	.502	2.56472

(R<sup>2</sup>) = Coefficient of Determination

The multiple regression analysis in Table 7 revealed a strong positive relationship between mathematics skills in Basic Science and students' achievement in genetics (R = 0.712, R<sup>2</sup> = 0.507, Adjusted R<sup>2</sup> = 0.502). This indicates that approximately 51% of the variance in students' achievement in genetics is jointly explained by ratio skills, probability skills, and graph interpretation skills. The results suggest that students who demonstrate higher overall mathematics competence are more likely to achieve better results in genetics, highlighting the importance of integrating multiple mathematical skills in Basic Science and Technology instruction.

**6.8 Hypothesis four**

There is no significant joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics.

**Table 8**

*Regression ANOVA of significant joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics*

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1841.361	3	613.787	93.312	.000 <sup>b</sup>
	Residual	1789.158	272	6.578		
	Total	3630.519	275			

The result in Table 8 shows that F-ratio of 93.312 with associated exact probability value of .000 was obtained. This probability value of 0.00 was compared with 0.05 set as level of significance for testing the hypothesis and it was found to be significant since the obtained probability value of 0.000 is less than 0.05. Thus, the null hypothesis no significant predictive power of mathematics skills in Basic Science and Technology on

students' achievement in genetics was rejected. The researchers therefore, conclude that there is a significant joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics.

## **7 DISCUSSION OF THE FINDINGS**

### **7.1 Predictive power of ratio skills in basic science and technology on students' achievement in genetics**

The study's findings revealed that ratio skills account for approximately 20% of the variance in students' achievement in genetics, indicating a moderate level of influence. This suggests that students who possess stronger ratio skills are more likely to perform better in genetics. This reinforces the idea that mathematics and science learning are intertwined, and that enhancing students' ratio competence can directly contribute to improved understanding and performance in genetics. The subsequent regression analysis confirmed the significant predictive power of ratio skills on students' achievement, demonstrating that ratio skills play an essential role in understanding and solving genetic problems.

The predictive strength of ratio skills observed in this study may be due to the fact that genetics concepts inherently involve proportional reasoning. Students who are comfortable working with ratios can accurately analyze Punnett squares, determine the distribution of alleles, and relate numerical relationships to biological outcomes. Conversely, students with weaker ratio skills may struggle to connect abstract numerical concepts to the genetic phenomena they are studying, resulting in lower achievement (Akinsola & Olowojaiye, 2008). Another possible reason for the observed result is the instructional emphasis on mathematics within Basic Science and Technology. Students who have been exposed to exercises that integrate ratios in practical contexts, such as problem-solving in genetics, may have developed stronger cognitive links between mathematical and scientific concepts, enhancing their performance. Additionally, familiarity with ratio-related problem-solving strategies may reduce misconceptions and cognitive overload when interpreting genetic data (Bybee, 2013; Li, Schoenfeld, & diSessa, 2025).

This finding aligns with previous research emphasizing the critical role of mathematical reasoning in science learning. For example, Dehipawala, Lee, and Cheong (2014) noted that students' ability to manipulate and interpret ratios significantly affects their capacity to understand proportional relationships in scientific contexts. Similarly, Jerrim et al. (2023) found that ratio skills are essential in predicting students' academic performance in STEM subjects, including biology and genetics. In genetics, ratio skills enable learners to calculate genotypic and phenotypic ratios, interpret Mendelian crosses, and understand the probability of trait inheritance, all of which are central to mastering genetics concepts (Özdemir & Clark, 2022; Matthews et al., 2009).

Furthermore, the finding highlights the instructional implication that integrating mathematical skill development within Basic Science and Technology teaching can improve students' achievement in genetics. Teachers should therefore emphasize ratio exercises in genetics contexts, such as calculating probabilities of inheritance, analyzing Punnett squares, and comparing phenotypic and genotypic distributions. This approach supports the constructivist view that mathematical reasoning is not an isolated skill but a cognitive tool essential for understanding complex scientific phenomena.

## **7.2 Predictive power of probability skills in basic science and technology on students' achievement in genetics**

The findings of the study revealed that probability skills account for approximately 27% of the variance in students' achievement in genetics. This indicates that probability skills are a moderately strong predictor of students' performance in genetics. Students with stronger probability skills are likely to achieve higher scores in genetics, although other factors such as ratio skills, graph interpretation skills, teaching methods, and prior knowledge also play a role in determining academic achievement. Further analysis confirmed the significant predictive power of probability skills in Basic Science and Technology on students' achievement in genetics.

One possible reason for this result is that probability skills allow students to connect mathematical principles to biological phenomena, facilitating a deeper conceptual understanding of genetics. For instance, understanding independent and dependent events, calculating the probability of offspring traits, and using probability to

predict outcomes helps students navigate abstract genetic problems more confidently. As a result, students with stronger probability skills can more accurately predict genetic outcomes, improving their performance. Another possible reason for the outcome of the finding is the instructional exposure students receive. Students who have engaged in problem-solving exercises that integrate probability concepts in practical science contexts may develop stronger cognitive links between mathematics and genetics. This exposure reduces errors and enhances reasoning ability when solving genetic problems (Bybee, 2013; Dehipawala, Lee, & Cheong, 2014). Additionally, probability skills may support critical thinking and analytical reasoning, which are important for understanding patterns in inheritance and experimental results.

This finding is consistent with prior research emphasizing the importance of probability reasoning in understanding genetics concepts. Genetics inherently involves predicting outcomes of genetic crosses and calculating the likelihood of trait inheritance. Students who are proficient in probability can accurately determine expected genotypic and phenotypic ratios, apply Mendelian laws effectively, and interpret results from monohybrid and dihybrid crosses (Özdemir & Clark, 2022; Matthews et al., 2009). Conversely, students with weaker probability skills may struggle with these calculations, leading to misconceptions and lower achievement.

### **7.3 Predictive power of graph interpretation skills in basic science and technology on students' achievement in genetics**

The finding of the study revealed that graph interpretation skills account for approximately 16% of the variance in students' achievement in genetics. This indicates that graph interpretation skills are a significant, but relatively weaker, predictor of students' performance compared to ratio and probability skills. The result suggests that students with stronger graph interpretation skills tend to perform better in genetics, although other factors such as ratio skills, probability skills, teaching methods, and prior knowledge also contribute substantially to academic achievement. Further analysis confirmed the significant predictive power of graph interpretation skills in Basic Science and Technology on students' achievement in genetics.

One possible reason for the relatively lower predictive power of graph interpretation skills is that while visual interpretation supports understanding, genetics achievement also heavily depends on mathematical reasoning, particularly ratio and probability skills. Graph interpretation alone may not equip students to perform calculations or predict inheritance outcomes, which are essential components of genetics learning. Consequently, students with strong graph skills but weaker mathematical reasoning may still struggle with solving genetic problems, resulting in a lower overall contribution to achievement. Another possible reason is instructional emphasis. Many classroom activities may focus more on problem-solving using ratios and probabilities rather than on analyzing graphical data. If students have limited exposure to interpreting graphs in genetics contexts, their skills in this area may not develop fully, reducing its impact on achievement. Furthermore, the cognitive demands of translating graphical information into meaningful genetic conclusions may vary among students, affecting the predictive strength of graph interpretation skills (Bybee, 2013; Dehipawala, Lee, & Cheong, 2014).

This finding is consistent with prior research emphasizing the importance of visual literacy and data interpretation in science learning. For instance, Wineburg and Grossman (1998) highlighted that students' ability to interpret graphs and visual data significantly affects their understanding of scientific concepts. Similarly, Kosslyn (2006) argued that graph comprehension enhances reasoning in problem-solving tasks, particularly in quantitative science concepts. In the field of genetics education, studies by Lewis and Wood-Robinson (2000) and Duncan and Reiser (2007) reported that students who can analyze graphs effectively demonstrate better understanding of inheritance patterns and experimental results. Moreover, research by Gkitzia et al. (2013) showed that visual and graphical skills positively correlate with achievement in biology, supporting the notion that graph interpretation contributes to students' academic success.

#### **7.4 Joint predictive power of mathematics skills in basic science and technology on students' achievement in genetics**

The finding of the study revealed that approximately 51% of the variance in students' achievement in genetics is jointly explained by ratio skills, probability skills,

and graph interpretation skills. This indicates a strong combined predictive influence of mathematics skills on students' performance in genetics. The result suggests that when these skills are considered together, they provide a more powerful explanation of students' achievement than when considered individually. Further analysis confirmed the significant joint predictive power of mathematics skills in Basic Science and Technology on students' achievement in genetics. The strong joint predictive power observed in this study may be attributed to the complementary nature of the three mathematical skills. Ratio skills enable students to determine genetic proportions, probability skills help in predicting the likelihood of trait inheritance, while graph interpretation skills support the analysis of data and identification of patterns. When combined, these skills provide a comprehensive cognitive framework that allows students to approach genetics problems from multiple perspectives, thereby improving their overall performance. This supports the view that meaningful learning in science requires the integration of multiple cognitive skills rather than reliance on a single competency (Bybee, 2013; Schoenfeld, 2016).

Another possible reason for this result is that genetics is inherently interdisciplinary, requiring students to apply different forms of reasoning simultaneously. For example, solving genetic problems often involves calculating ratios, applying probability rules, and interpreting results presented in tables or graphs. Students who are proficient in all these areas are more likely to demonstrate deeper understanding and higher achievement. Conversely, deficiencies in any one of these skills may limit students' ability to fully grasp genetics concepts, thereby affecting their overall performance.

This finding is consistent with existing literature that emphasizes the integrated role of mathematical competencies in science learning. For instance, Tai, Liu, Maltese, and Fan (2006) reported that students' overall mathematics proficiency significantly predicts their success in science subjects, particularly in areas requiring analytical reasoning such as genetics. Similarly, Sadler and Tai (2007) found that a combination of mathematical skills contributes significantly to students' achievement in biology and other STEM-related disciplines. In the same vein, Duncan and Reiser (2007) highlighted that students' ability to coordinate multiple forms of reasoning, including numerical, probabilistic, and graphical thinking, enhances their understanding of complex scientific concepts. The finding also reflects the effectiveness of integrated instruction in Basic

Science and Technology. When teaching approaches emphasize the connection between mathematics and science concepts, students are more likely to develop transferable skills that enhance their academic achievement. This aligns with the recommendations of interdisciplinary STEM education, which advocate for the integration of mathematics into science teaching to improve learning outcomes (Honey, Pearson, & Schweingruber, 2014).

## **8 CONCLUSION OF THE FINDING**

Based on the findings of the study, it can be concluded that mathematics skills in Basic Science and Technology, specifically; ratio skills, probability skills, and graph interpretation skills are significant predictors of students' achievement in genetics. Individually, each of these skills contributes meaningfully to students' understanding and performance, with probability skills showing the highest predictive influence, followed by ratio skills and graph interpretation skills. More importantly, the combined effect of these mathematical skills accounts for a substantial proportion of the variance in students' achievement in genetics, indicating that students who possess a strong foundation in these skills are more likely to perform better. This suggests that genetics learning is not solely dependent on biological knowledge but also on students' ability to apply mathematical reasoning in solving genetic problems. Therefore, it is concluded that the integration of mathematics skills into the teaching and learning of Basic Science and Technology is essential for improving students' academic achievement in genetics. Enhancing students' competence in ratio, probability, and graph interpretation skills will likely lead to better understanding of genetic concepts and improved learning outcomes.

## **9 RECOMMENDATIONS**

Based on the findings of this study, the following recommendations are made:

1. Teachers of Basic Science and Technology should deliberately integrate mathematics skills, particularly ratio, probability, and graph interpretation into the teaching of genetics to enhance students' understanding and achievement.

2. Curriculum planners should design instructional materials and curriculum content that promote the effective integration of mathematics and science concepts, especially in topics such as genetics that require quantitative reasoning.
3. Students should be provided with regular practice in solving genetics-related problems that involve ratio calculations, probability predictions, and graph interpretation to strengthen their analytical and problem-solving skills.
4. Teachers should adopt learner-centered instructional strategies such as problem-based learning, inquiry-based learning, and the use of visual representations to help students develop both mathematical and scientific reasoning skills simultaneously.
5. Educational stakeholders, including school administrators and policymakers, should organize workshops and training programs for teachers to improve their competence in integrating mathematics skills into science instruction.
6. Instructional resources such as charts, graphs, simulation tools, and practical activities should be made available in schools to support the teaching of genetics and enhance students' graph interpretation skills.
7. Assessment practices should be structured to evaluate not only students' theoretical knowledge of genetics but also their ability to apply mathematical skills in solving genetics problems.
8. Further studies should be conducted to explore other factors that may influence students' achievement in genetics, such as teaching methods, students' attitudes, and learning environments, since mathematics skills alone do not account for all the variance in achievement.

#### **AUTHORS' CONTRIBUTION**

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Obiageli Loretta ANIAKU, Mercy Ifunanya ANI, and Bianca Uzoamaka MBONU-ADIGWE conceptualized and designed the study, developed the research framework, and supervised the overall implementation of the research work.

Kelechi Chinemerem MEZIEOBI, Blessing C. ANAKPUA and Bianca Uzoamaka MBONU-ADIGWE were responsible for the development of research instruments, data collection, and initial data organization.

Benson Chukwunonso EZEANYI, and Christian Chinasaokwu JOB performed the statistical analysis and contributed to the interpretation of the results.

Christiana Ogonna ODIMKPA, Peter Eson MUSA, Blessing Chinyere CLEOPAS and Michael OLAGOKE conducted the literature review and contributed to the writing of the background and discussion sections of the study.

Obiageli Loretta ANIAKU and Bianca Uzoamaka MBONU-ADIGWE assisted in data collection, data cleaning, and proofreading of the manuscript.

Chinyere CLEOPAS and Michael OLAGOKE contributed to the final writing, editing, and formatting of the manuscript for publication.

All authors read and approved the final manuscript.

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### **Authors' Contribution**

All authors contributed equally to the development of this article.

### **Data availability**

All datasets relevant to this study's findings are fully available within the article.

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